Title: 2005-2015 UMD-LLO Lake Superior Mooring deployments

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Introduction

This document contains a description of moored data collected over a 10+ year period in Lake Superior. Data from thermistors (temperature) and Acoustic Doppler Current Profilers (ADCPs), which measure currents and acoustic backscatter intensity, are included. The data is from 72 separate mooring deployments, and includes 773 individual thermistor records and 32 ADCP records. This archive covers deployments that took place in years 2005 through 2014; this includes data into 2015. A subsequent archival entry is being prepared that will cover deployments made in 2015-2020.

Locations

There are multiple sites throughout Lake Superior (Figure 1). During an especially intensive period from 2009-2012, up to 8 locations were occupied simultaneously. Three of the mooring locations are co-located with NDBC surface buoys. The sites are named as follows:

Name	Description	Nominal lat (dd° mm.m’ N)	Nominal lon (dd° mm.m’ W)	Nominal depth (m)	comment
FWM	Far Western Mooring	47° 2.9’	91° 14.9’	170	
WM	Western Mooring	47° 19.3’	89° 48.1’	185	Close to NDBC 45006
CM	Central Mooring	48° 1.3’	87° 46.1’	257	Close to NDBC 45001
EM	Eastern Mooring	47° 32.2’	86° 34.3’	212	Close to NDBC 45004
NM	Northern Mooring	48° 30.0’	87° 3.0’	200	
SM	Southern mooring	47° 2.0’	86° 40.0’	384	

FEM	Far Eastern mooring	47° 28.5’	85° 14.9’	247	
45027	McQuade onshore*	46° 51.9’	91° 55.6’	52	NDBC 45027
45028	McQuade offshore*	46° 48.7’	91° 50.1’	52	NDBC 45028
GM1	Grand Marais 1	47° 40.0’	90° 26.0’	153	
GM2	Grand Marais 2	47° 33.4’	90° 20.7’	167	

* Surface meteorology buoys for spring deployment

We include approximate positions and depths for these sites. Each individual deployment may not be exactly at this location. All deployments are within a few km of the nominal location, and actual deployment positions are available in the summary tables and in the files provided.

Deployment method

Moorings have been deployed by researchers at UMD’s Large Lakes Observatory continually since Fall 2005 (Figure 2). Two primary types of platforms are included. Subsurface moorings consist of a large concrete anchor, an acoustic release, a length of steel cable with pre-measured and marked locations, to which thermistors, pressure sensors, and acoustic Doppler current meters (ADCPs) are attached, and subsurface flotation, typically at around 10m depth to keep them below the draft of the largest vessels on the lake (Figure 3). On these moorings, pressure sensors are deployed at one or more depths to determine the actual deployed depth of the mooring, as opposed to the design depth of the mooring. By using the measured pressures and knowing the depth offset between the pressure sensors and the other gear, we can determine the actual deployed depth of all sensors. Since the top float for these moorings are typically at about 10m depth, we do not measure temperature in the top 10m of the water column. This is an issue if near-surface thermal structure is of interest; however, several of the mooing sites were chosen to be close to NDBC buoys, which provide surface water temperature in the spring-fall. We do not include that data in this archive since it was not collected by this lab. Users are encouraged to acquire the NDBC buoy data (ndbc.noaa.gov) and include it if positively stratified conditions are being examined. During the winter months, the NDBC buoys are not deployed; however, thermal structure in the winter is typically very uniform near the surface and the 10m temperature measurement is likely adequate for most purposes.

The second kind of platform are surface buoys, below which thermistor strings are deployed, providing temperature at a range of depths including the upper 10m of the water column. The meteorology data from these buoys can be accessed through the Great Lakes Observing System (glos.us) data portal or through ndbc.noaa.gov.

Deployment naming convention

The individual deployments (data collected between a deployment and subsequent recovery) are named as follows: The location name (i.e. WM), a season (S or F, for Spring or Fall), and a two-digit year (-2000). For instance, WMS09 is the mooring deployed at the Western Mooring site in Spring of 2009.

Mooring failures

There have been three failed moorings, which account for the occasional gaps in the data (Figure 2). All of these failures have been due to poor quality wire, an issue we did not initially appreciate. WMF09 failed on 9 December 2009, less than 2 months after deployment, when it lost its top float. All other equipment was recovered but instruments were at the wrong depths after the failure (the top float was eventually recovered on the Keweenaw peninsula). Likewise, CMF09 failed just one month later, on 9 January 2010, just below the top float. All equipment was recovered by grapple but data after 9 January reflect that instruments were sitting on the bottom of the lake. EMS12 failed just above the release- the release and a single thermistor (not included here) were recovered.

Types of data

The primary types of data collected were temperature at a range of depths, and currents and backscatter data from ADCPs. Temperature has been collected using a variety of thermistors: Brancker Research (RBR) thermistors including the TR-1000, TR-1050, TR-1060, TR-SOLO (all temperature), and TR-2050 (temperature and pressure), and from SeaBird Scientific (SBE-39, temperature, or temperature and pressure). Over the 10 years represented here, technology advanced significantly, so that the temporal resolution changed from 10- or 20-minute sampling rates in early years to a rapidly as 1Hz in later years.

The two meteorology buoys (spring deployments at 45027 and 45028) carried thermistor strings, as opposed to individual thermistors. In early years, we used NexSens thermistor strings, and in later years, RBR XR-420 thermistor strings. The results from the thermistor strings are mixed; we frequently would have one or more thermistors fail on a string after a few years of use. For ease of processing, these datasets have been broken up into individual files, equivalent to those for individual thermistors.

All ADCP data presented here was collected with RDI Workhorse ADCPs, primarily 300kHz instruments but including one 600kHz instrument. ADCP compasses are calibrated on land prior to all deployments.

Summaries

Four summary tables of metadata are included in this submission. They are included as .xlsx (Microsoft Excel-readable) files.

- **Mooring_summary_table.xlsx** A deployment summary (71), consisting of basic information about each individual deployment.
- **Thermistor_summary_table.xlsx** A thermistor summary (773), consisting of basic information about each individual thermistor dataset, including location, depth, sampling rate, sensor type, and filename.
- **Pressure_summary_table.xlsx** A pressure sensor summary, similar to the thermistor summary, but for pressure records.
- **ADCP_summary_table.xlsx** An ADCP deployment summary, including sampling interval, vertical bin size, deployment duration, location, depth, and orientation.

Data

Two types of data are available for thermistor and ADCP deployments: raw and hourly averaged. Most users will only ever use the hourly averaged data.

Raw Data

The raw data is included in a set of directories entitled ‘20xx mooring deployments’, inside of which are subdirectories corresponding to each individual deployment during that year. Inside each of these is a subdirectory called ‘thermistors’ and, when appropriate, ‘ADCPs’.

For thermistors, the raw data files have filenames of the form sssss_yymmdd.mat, where sssss is the serial number of the deployed sensor, yy, the recovery year, mm the recovery month, and dd the recovery day. Within each file are the following variables:

- t. Time in MATLAB time convention (fractional days since 1 Jan 0000). The time zone is UTC.
- T. Temperature in degrees Celsius
- dep. Sensor depth in meters
- Z. Water depth in meters
- lat. Latitude in degrees north
- lon. Longitude in degrees west
- SN. Serial number of sensor (redundant with filename)
- P (if applicable). Pressure in decibars. This pressure is absolute (i.e. it includes atmospheric pressure).

These files are minimally processed; in other words, they may contain pre- and post-deployment “deck data” that a user will need to trim from the record before use.

Raw data from ADCPs is included in the mooring deployment directories; not all deployments included ADCPs. The naming convention for raw data files is NNNNN_UD_ZZ.mat, where NNNNN is the name of the deployment, UD is either U or D for upward or downward facing, and ZZ is the deployed depth of the ADCP. For example, WMS09_U_81.mat is an ADCP deployment from Western Mooring in Spring 2009, upward looking, with the instrument at 81m depth. The data is in a MATLAB file created by Rich Palcowicz’s rdradcp.m code from the raw binaries from the ADCPs. Data is in a structure named D. Immediately relevant variables include D.mtime, the time of the sample in MATLAB time format in UTC, D.east_vel, D.north_vel, the east and north components of velocity in m/s, and D.config.ranges, the distance in meters of each bin from the ADCP.

Raw data availability

Filename	# of files
2005 mooring deployments.zip	6
2006 mooring deployments.zip	17
2007 mooring deployments.zip	22
2008 mooring deployments.zip	103
2009 mooring deployments.zip	152
2010 mooring deployments.zip	149
2011 mooring deployments.zip	167
2012 mooring deployments.zip	62
2013 mooring deployments.zip	69
2014 mooring deployments.zip	80

Hourly Data

Hourly averaged data is created for each deployment to provide a more user-friendly format and are included in the directory **hourly_data_2005-2015.zip**. These files provide hourly-averaged temperature, velocity, and backscatter intensity on a regular grid for each deployment with pre- and post-deployment data trimmed off. Hourly averages are hour-centered i.e. the data reported for 02:00 is data collected from 01:30 to 02:30. When present, ADCP data bins are limited according to $R_{max} = D\cos(\Theta)$ where R_{max} is the maximum acceptable range, D is the distance from the ADCP to the surface/bottom, and Θ is the beam angle (Gordon 1996). The file naming convention is the name of the deployment, as described above, plus a ‘h’ to indicate that it is hourly-averaged data. Each of these files in, cludes

- t. Time in MATLAB time convention (fractional days since 1 Jan 0000). The time zone is UTC.
- T. Temperature in degrees Celsius, where rows represent times and columns correspond to the different sensors
- dep. A vector of sensor depths, in meters, corresponding to the columns of T.
- Z. Water depth in meters
- lat. Latitude in degrees north
- lon. Longitude in degrees west
- SN. A vector of serial numbers, corresponding to the columns of T.

And when appropriate:

- adcp_SN. Serial # of the ADCP
- adcp_dep. Deployed depth of ADCP, in meters
- bins. Depth of ADCP sampling bins, in meters, corresponding to the columns of velocity and intensity data
- east_vel. east velocity, m/s (velocities are all in the direction the water is going, where rows represent times and columns correspond to the different bin depths)
- north_vel. north velocity, m/s
- vert_vel. Vertical velocity, m/s. Positive is upward flow.
- intens. backscatter amplitude, averaged between four beams, where rows represent times and columns correspond to the different bin depths

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Bibliography

Gordon, R.L., 1996: Acoustic Doppler Current Profiler Principles of Operation: A Practical Primer. 2nd ed.

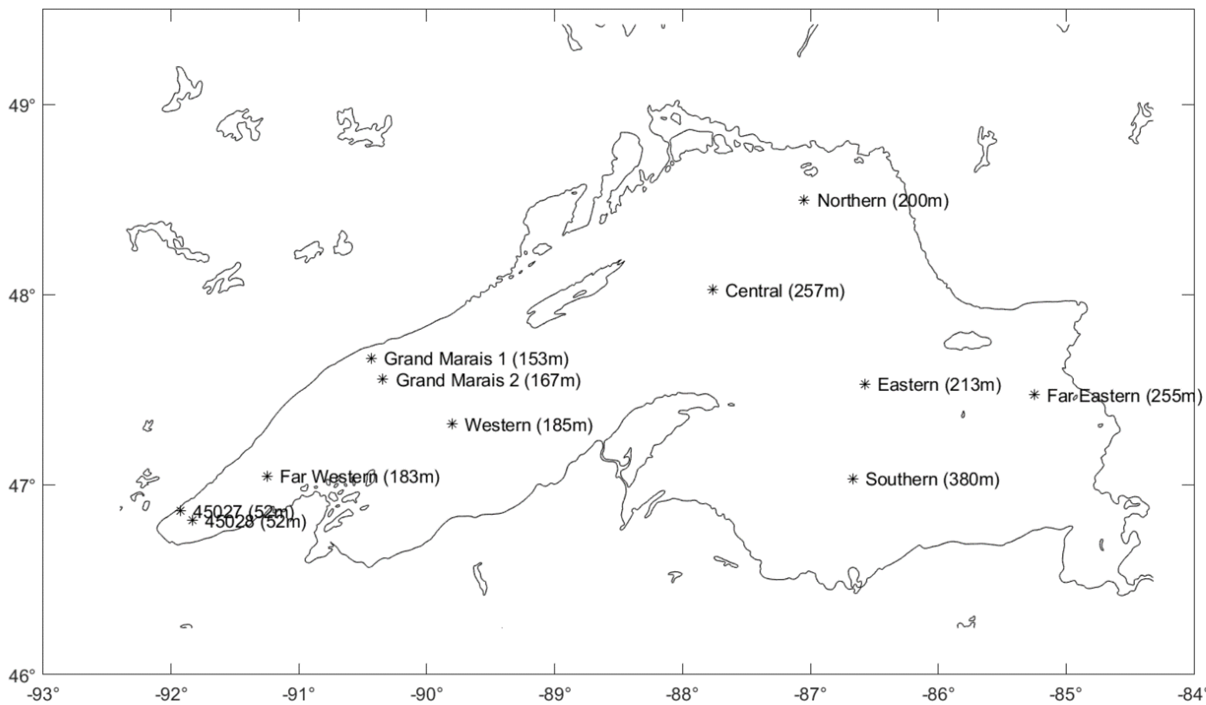

Figure 1. Mooring locations on Lake Superior, USA/Canada. NM and FEM are in Canadian waters.

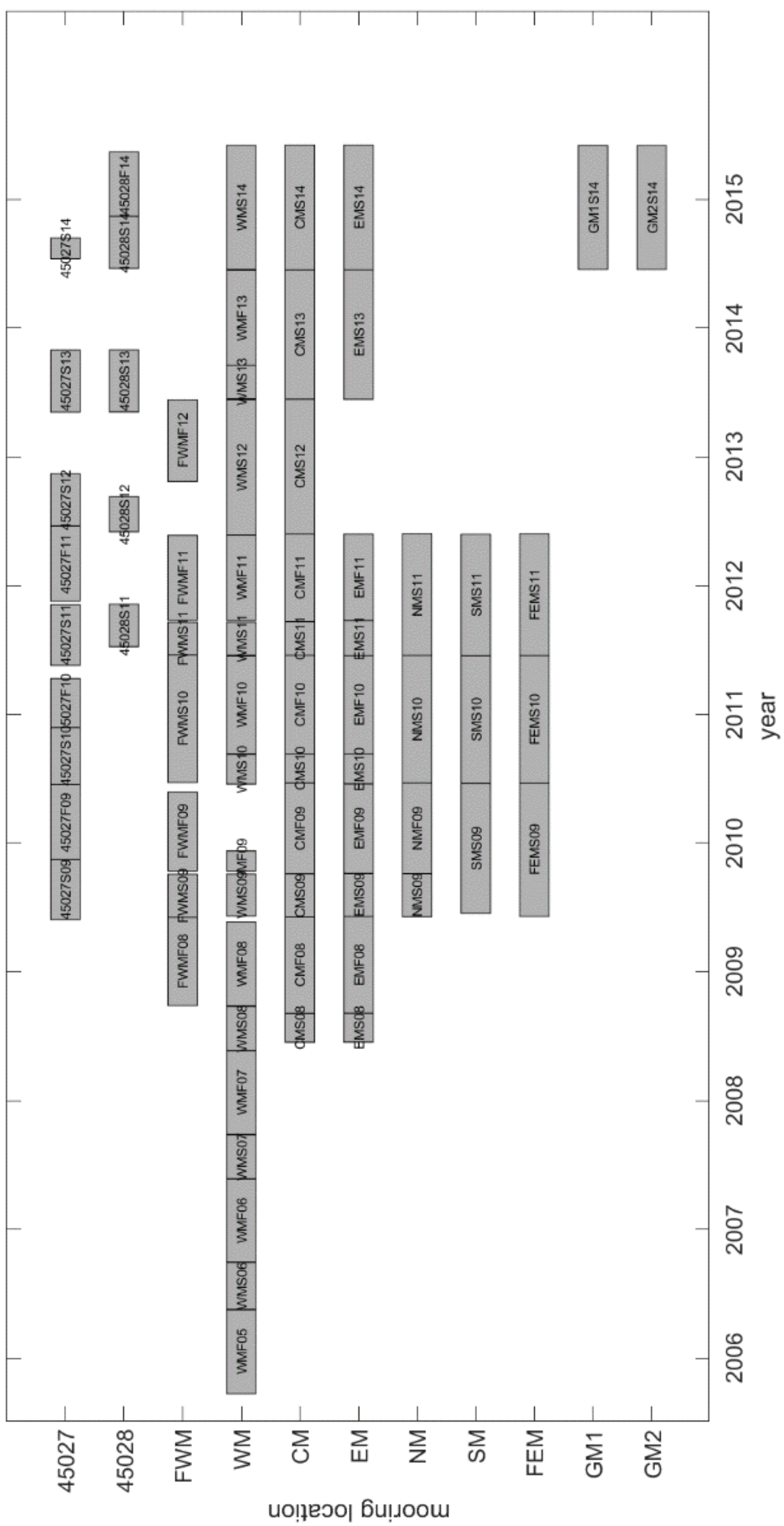

Figure 2. Data availability for each mooring

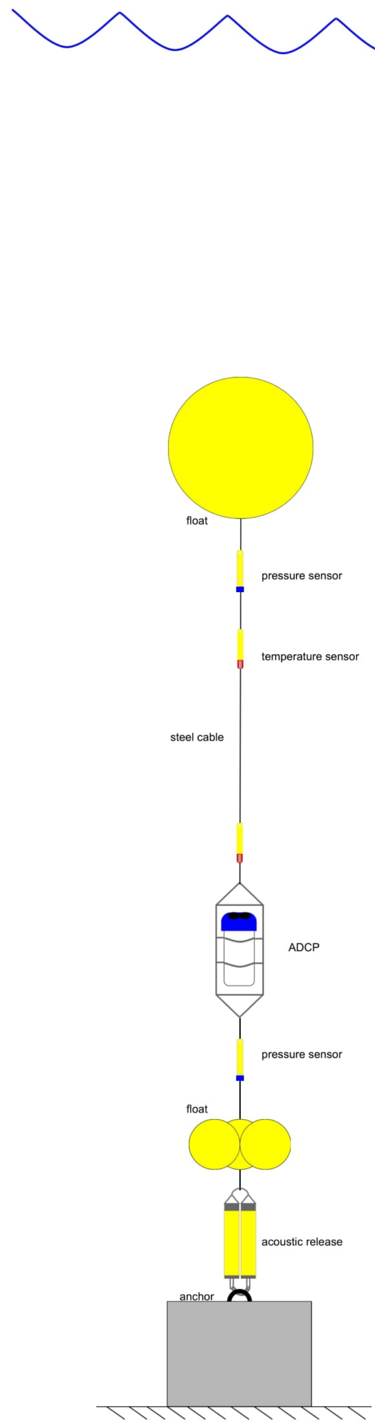

Figure 3. Basic mooring schematic.